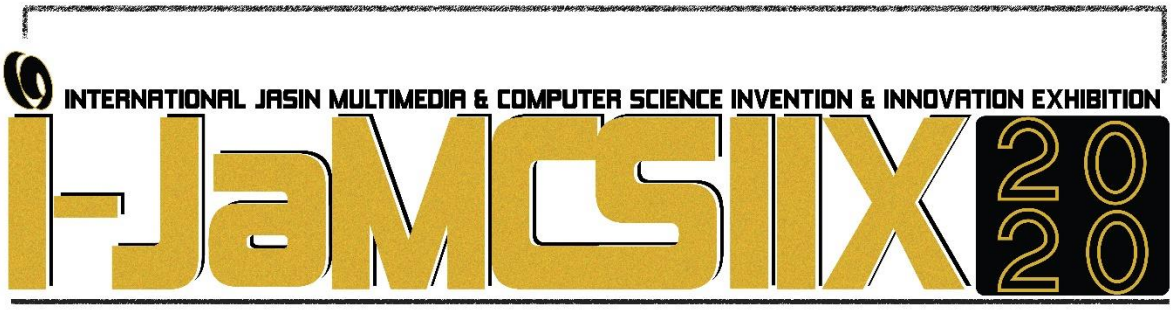

Prototype of New Composite Weightage and Offset Thickness Design of Acetabular Cup in THR

Muhammad Faris Abd Manap[1], Solehuddin Shuib[2], Nor Shamimi Shaari [3], Mahfuzah Zainudin[4] and Muhamad Faris Syafiq Khalid[5]
[1,3,4]Universiti Teknologi MARA Cawangan Pulau Pinang
muhammadfaris@uitm.edu.my
[2]Universiti Teknologi MARA Shah Alam
solehuddin2455@uitm.edu.my
[5]Universiti Teknologi MARA Cawangan Johor
farissyafiq@uitm.edu.my

ABSTRACT

Defect bone at hip joint of human body will required surgical operation which commonly known as Total hip replacements (THR). Succession rate of the surgical procedures depending on many factors. Currently the THR operation could not guarantee 100% succession rate which dislocation, fracture, inflammation, edge-loading effect and rejection of new materials are among the concerned issues. The objective of this study particularly to make a prototype of new composite weightage and offsetting thickness of acetabular cup in order to increase the surgical post-operative succession rate. Firstly, a new design was drawn using SolidWorks software which the articulation area was offset by increasing the superior region. Then, the FE analysis conducted via ANSYS WORKBENCH to simulate the effect of offsetting the acetabular cup design. Secondly, a new material composition of Ep-UHMWPE with various weightage and thickness were studied experimentally according to ASTM D638-02A. Simulation and experimental analysis results show good agreement that 5mm thickness improvise mechanical properties up to 66% in term of Von-Mises stress, total deformation and contact pressure. Thus, offsetting superior region thickness could potentially improvise the implant lifespan especially during the normal gait condition. Adding Ep (Epoxy) into existing material (UHMWPE) at ideal weightage also increasing the mechanical properties of the acetabular cup. However, further studies are required to design a second prototype with higher articulation efficiency and material's biocompatibility.

KEYWORDS: Acetabular Cup, Finite Element Analysis (FEA), THR Design, Composite Material

1 INTRODUCTION

Ultra-High Molecular Weight Polyethylene (UHMWPE) is widely employed thermoplastic used in advanced engineering application due to its excellence properties such as high impact

resistance [1] and wear resistance compared to other thermoplastic materials [2], [3]. For decades, the increasing demand of artificial joint implant from the global market has made UHMPWE to become one of major research interest among researchers and industries. Joint implant specifically at the hip implant required these types of materials especially in Total Hip Replacement (THR).

On the other hand, designing a hip implant also pivotal in order to reduce adverse effect post-operations principally on the motion [4]. Articulation of femoral head with acetabular cup need to be smooth as many issues on stress effect, contact pressure, crack, dislocation and wear could potentially require revision after operation [5]. Thus, it is vital to study the mechanical aspect of any implant design and material selection that will improve the implant itself.

2 OBJECTIVE

The objective of this study is to improve the implant life particularly on the articulation area of the THR. New composite weightage added with offset design of acetabular cup may surpass the normal implant life in term of mechanical properties aspect.

3 SIGNIFICANCE (S)

The existing material and design of hip implant for THR are vary depending on various conditions. Currently, UHWMPE is the most usage material for the acetabular cup as it is considered as the most biocompatible to human body with less adverse effect on the patient. However, data shows that UHMWPE could not give a higher lifespan with wear, cracks, deformation and etc. are among issues related. The design of the implant also need to revamp as issues related to motion and stress could be potentially dangerous to the patients.

4 METHODOLOGY

Two separate experimental procedures was carried out to study the mechanical properties of Ep-UHMWPE with different thickness according to ASTM standard. The thickness was chosen at 3mm and 5mm, respectively considering the acetabular cup thickness requirement. The coding of the formulation had been tabulated for every variation conducted in this experimental work with five different variants. Epoxy resins were obtained from the Faculty of Applied Science, UiTM with the coding of Morcote BJC-29 supplied by Vistec Technology Sdn Bhd. Meanwhile, UHMWPE graded GUR 4120 was supplied from Ticona Engineering Polymer, China in powdered form with molecular weight of $5x10^{6}gmol^{-1}$ and density of 0.93 g/cm^{3}. The mass was determined by density equation as equation below.

The samples were loaded into a universal testing machine (Shimadzu) possessed by Faculty of Applied Science, Universiti Teknologi MARA with the machine code name of UiTM/PS01/A/090108/20080001118. The machines equipped with 20kN load cell capability. Test was conducted under ambient laboratory conditions, 23 ± 1°C. The load was applied at a constant displacement rate of 3mm/min.

A prototype named P0 was developed with new design of offsetting the superior region by increasing to 5mm thickness. The design was drawn by using SolidWorks and FE analysis was conducted via ANSYS WORKBENCH V15. A constant loading mimicking normal gait cycle was exerted on the femoral head at 2450N [6–8]. Two constrained area were

applied at the pelvis bone as shown in Fig. 1. Two seperates analysis were conducted with normal design and offsetting design in order to compare the new design optimization in term of mechanical properties.

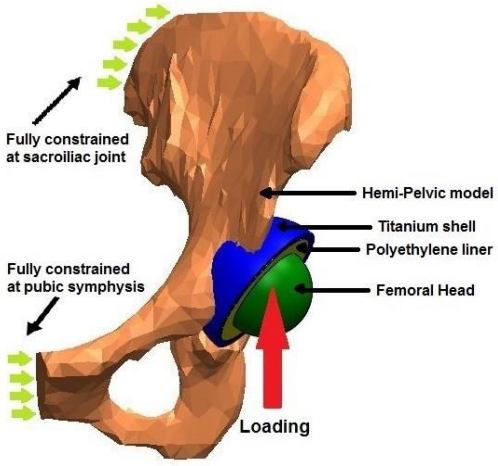

Fig. 1 The FE modelling and boundary condition of offset design acetabular cup

5 RESULT

Experimental procedures as accordance to ASTM [9] carried out find that EpUHMWPE with 5mm thickness produced higher Young's Modulus which increase stiffness of the materials. EpUHMWPE2 recorded the highest values of Young's Modulus in both thickness condition. Adding weightage more than 2% will reduced the stiffness of the composite materials.

Fig. 2 a) and b) shows the tensile stress-strain curves of the composite variant of 3mm and 5mm thickness, respectively that were tested in this experiment. The 3mm thickness variant shows that EpUHMWPE2 produced the highest ductility properties compared to other variants which highest strain value of 2.75 recorded in the testing with almost more than 25% elongation. On the other hand, the 5mm thickness variant shows that EpUHMWPE2 exhibits highest brittleness compared to other variant. It is important that the superior region of the acetabular cup to produced less ductility in order to increase articulation motion without deformation.

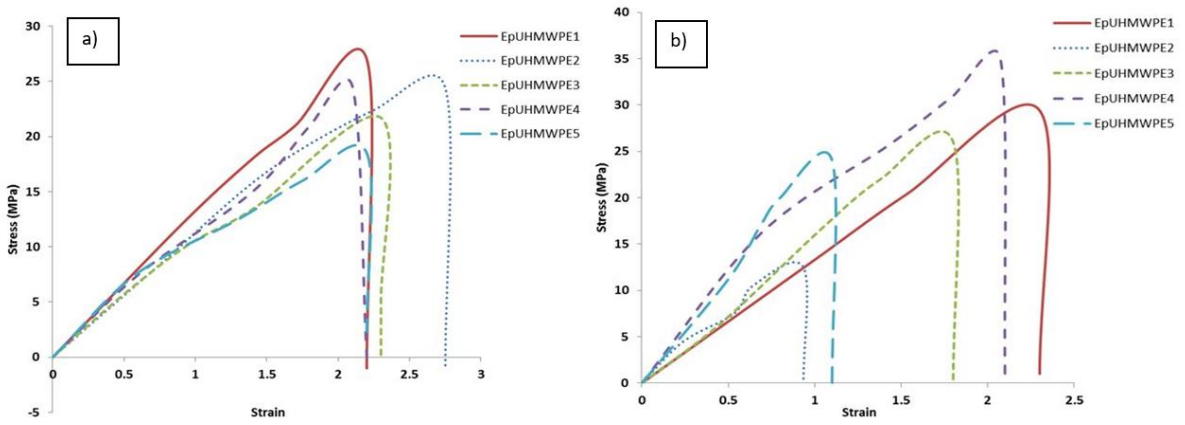

Fig. 2: The tensile stress-strain distribution upon new weightage of EpUHMWPE materials. a) The 3mm thickness condition, b) The 5mm thickness condition

On the other hand, the simulation conducted via ANSYS WORKBENCH V15 shows that new offset thickness design with new composite materials improved the mechanical properties up to 66% in term of Von-Mises stress, total deformation and contact pressure compared to existing material and design.

6 CONCLUSION

A prototype named P0 was designed based on the analysis conducted via experimental weightage and FE analysis. Offsetting the superior region to 5mm thickness may increase the mechanical properties up to 66% where thickness plays important role in order to reduce concentration stress when doing daily living activities (ADL). The experimental data also agreed that 5mm thickness sample at appropriate weightage formulation will perform better compared to 3mm thickness sample. However, further studies are required to design a robust offset superior region thickness and material biocompatibility thus, implementation could be made in future.

REFERENCES

[1] B. P. Chang, H. M. Akil, R. M. Nasir, and S. Nurdijati, “Mechanical and Antibacterial Properties of Treated and Untreated Zinc Oxide filled UHMWPE Composites,” J. Thermoplast. Compos. Mater., vol. 24, no. 5, pp. 653–667, 2011.

[2] M. Niinomi, L. Wang, T. Enjitsu, and K. Fukunaga, “Fatigue characteristics of ultra high molecular weight polyethylene with different molecular weight for implant material.,” J. Mater. Sci. Mater. Med., vol. 12, no. 3, pp. 267–72, 2001.

[3] J. C. Baena, J. Wu, and Z. Peng, “Composites in Arthroplasty Applications : A Review,” Lubricants, vol. 3, pp. 413–436, 2015.

[4] N. Faiqa Ismail, S. Shuib, M. A. Yahaya, A. Z. Romli, and A. A. Shokri, “Finite Element Analysis of Uncemented Total Hip Replacement: the Effect of Bone-Implant Interface,” Int. J. Eng. Technol., no. January, pp. 230–234, 2018.

[5] G. Tsikandylakis, M. Mohaddes, P. Cnudde, A. Eskelinen, J. Kärrholm, and O. Rolfson, “Head size in primary total hip arthroplasty,” EFORT Open Rev., vol. 3, no. 5, pp. 225–231, 2018.

[6] G. Bergmann et al., “Hip contact forces and gait patterns from routine activities,” J. Biomech., vol. 34, no. 7, pp. 859–871, 2001.

[7] K.-H. Widmer, “A simplified method to determine acetabular cup anteversion from plain radiographs,” J. Arthroplasty, vol. 19, no. 3, pp. 387–390, 2004.

[8] D. Kluess, D. Kluess, I. Begerow, P. Goebel, W. Mittelmeier, and R. Bader, “Analysis of Liner Deformation and Stress in Total Hip Replacements Considering Implant Materials, Position and Head Size,” Orthop. Proc., vol. 94-B, no. SUPP_XXXVII, p. 209, Sep. 2012.

[9] ASTM D1621-16, Standard Test Method for Compressive Properties of Rigid Cellular Plastics, ASTM International, West Conshohocken, PA, 2016, www.astm.org